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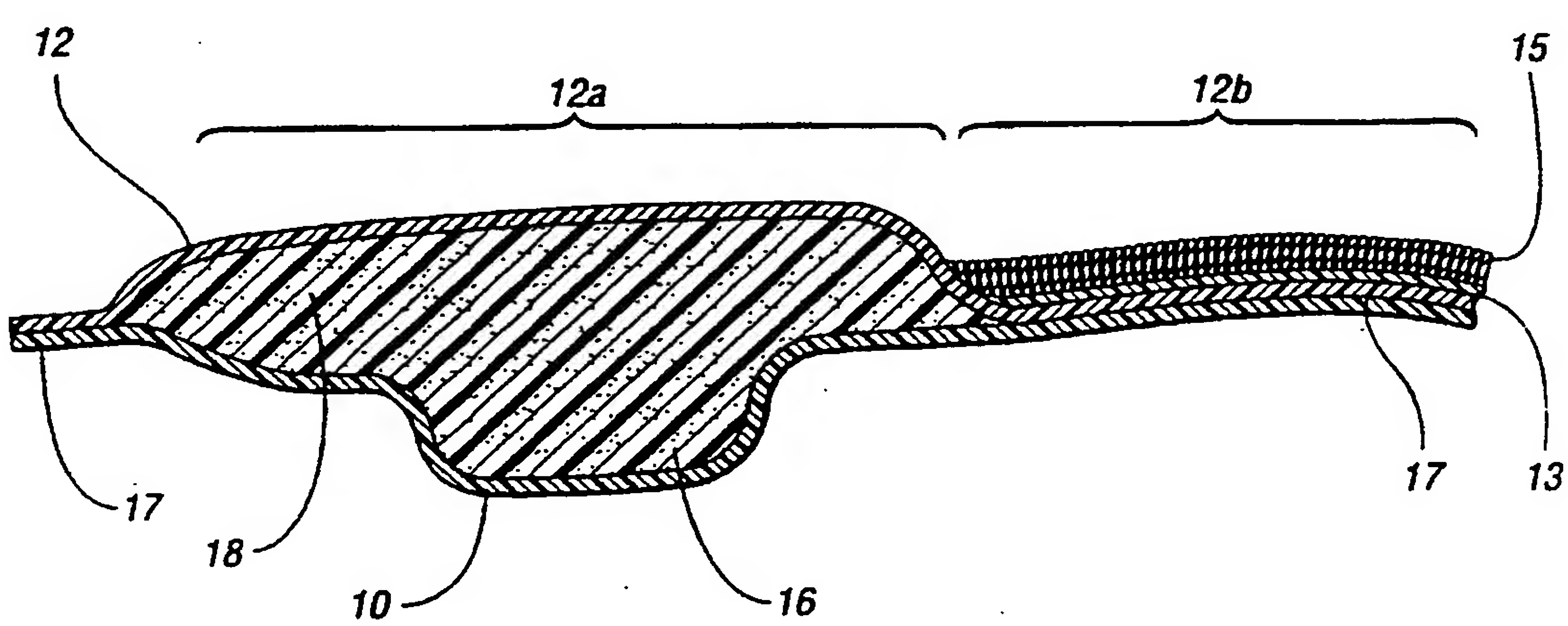
(54) Title: SANDWICH STRUCTURAL DOOR INNER PANEL



(57) Abstract: Integral door panel assemblies of low weight yet having the ability to support arm rest and pull strap without the need for complex steel stampings allow fabrication of vehicle components in a cost effective manner. The door panel assemblies are stressed sandwich structures containing a foam stiffening member (18) surrounded and bonded to inner (10) and outer structural skins (12). Preferred embodiments also have decorative trim (14) bonded thereto, most preferably in the same molding process. Door panel assemblies advantageously also contain a foam energy absorbing panel.

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SANDWICH STRUCTURAL DOOR INNER PANEL

TECHNICAL FIELD

The present invention pertains to vehicle door panels. More particularly, the present invention pertains to an integral, sandwich-structure door panel which incorporates a decorative trim layer, a structural outer skin, structural inner skin and foam stiffening layer, molded into a single unitary structure, offering weight and cost saving advantages. In the preferred embodiment, an energy absorbing foam panel is also included.

BACKGROUND ART

Conventional vehicle doors consist of a steel door skin, an outer (facing the passenger) decorative trim layer, an essentially non-structural outer skin, an energy absorbing panel, and a structural inner skin (facing the rear of the steel door skin). In addition, such vehicle doors also contain a strong steel beam to resist impact damage, and a further rather extensive metal (steel) stamping which performs numerous functions, including absorbing the loads of the pull strap and armrest loadings, typically on the order of 250 lbs. Between the steel door skin and the structural inner skin may be generally found the window mechanisms, etc. These are also mounted onto the steel stamping, which is termed by those skilled in the art as the "door inner". Finally, the door inner also strengthens the portion of the door interior adjacent the window, this area termed the "belt line".

The many separate components required of conventional construction renders vehicle doors heavy, due in large part to the weight of the door inner, and expensive as well, due to the number of separate components as well as to elevated assembly costs which separate components entail. It would be desirable to reduce the component count of vehicle doors, while maintaining performance and appearance, preferably lowering weight at the same time.

DISCLOSURE OF INVENTION

It has now been surprisingly discovered that by adopting a sandwich type stressed skin structure, a door "panel assembly" may be fabricated as a one piece structure performing the functions of the conventional components, without the use of a metal door inner.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 illustrates a prior art door assembly, illustrating a typical metal door inner.

FIGURE 2 illustrates a cross-section of a vehicle door "panel assembly" of the subject invention, containing a structural inner skin, a foam stiffening component, a structural outer skin, and a decorative trim layer.

FIGURE 3 illustrates another embodiment of the subject invention, where the outer structural skin also comprises a decorative trim layer.

FIGURE 4 illustrates a press layup suitable for forming the panel assembly of Figure 1.

FIGURE 5 illustrates one molding process employing a gapped mold where the layup may extend beyond the mold cavity per se.

FIGURE 6 illustrates a completed door panel prior to mounting door hardware.

FIGURE 7 illustrates a serpentine stiffening panel with integral energy absorbing foam panel.

FIGURE 7a is a cross-section of the door panel of Figure 7.

FIGURE 8 illustrates the response of subject invention panels to bending due to point loads.

BEST MODE FOR CARRYING OUT THE INVENTION

The invention pertains to a vehicle door "panel assembly" which comprises minimally a structural inner skin, a foam stiffening component, an outer, foam-encapsulating structural skin, and optionally a separate decorative covering or trim layer, all molded into a unitary, integral structure.

It is important that the structure of the present invention approach a "stressed skin" type of structure, where light but relatively stiff "foam stiffening components" are surrounded by or encapsulated within load bearing skins. In this manner, a structure having very desirable physical properties such as bending stiffness, strength to weight ratio, and the like, may be obtained. Most preferably, the integral panel assembly also includes an energy absorbing foam component or "panel", which may be integral with the foam stiffening component, or may be a separate component. It has been surprisingly found that by encapsulating the energy absorbing foam, this component may be made smaller while still retaining its energy absorbing structure.

The structural skins may be made of any moldable substance which will exhibit the required design characteristics of strength, modulus, flexibility, etc. These structural skins may be a high performance, substantially unfilled thermoplastic or thermoset polymer. Non-limiting examples include polyethylene, polypropylene, polyolefins in general, especially copolymers of polyethylene and/or polypropylene with 1-butene, 1-hexene, 1-octene, or the like, thermoplastic polyurethane, polycarbonate, polyacrylate, polystyrene, acrylonitrile butadiene styrene copolymers (ABS), epoxy resin, reaction injection molded polyurethane and polyurethaneurea (RIM), bismaleimide, cyanate curable polyester melamine/formaldehyde, phenol/formaldehyde, novolak, sheet molding compound, and the like.

Preferably, however, the structural skins are filled polymers, particularly fiberglass reinforced resins such as fiber reinforced polypropylene, phenol/formaldehyde or epoxy, or resins containing reinforcing fillers such as long or short fibers, for example glass, mineral, and natural fibers, glass or mineral flakes, woven fabric, non-woven fabric, and the like. The inner structural skin and outer structural skin need not be made of the same material, so long as the respective materials can adhere together in the mold or bond to each other in the mold by means of adhesive. Particularly preferred structural skin materials include GMT (glass mat reinforced thermoplastic), TPO (thermoplastic polyolefin) PVC (polyvinylchloride and its related copolymers), flax fiber-filled polypropylene, resin-filled wood fiber, woodstock, and glass fiber-containing polyurethane. Such materials are well known, and each is available from numerous commercial sources. Suitable adhesives useful for bonding of otherwise incompatible substrates or for facilitating consolidation at lower temperatures and/or pressures include curable polyester adhesives, polyurethane adhesives, epoxy adhesives, cyanate adhesives, bismaleimide adhesives, cyanoacrylate adhesives, silicone adhesives, and the like. preferably, the structural skins are of compatible materials which will make a strong bond with each other as a result of the molding process.

The outer structural skin and decorative trim layer may be separate components or may constitute the same component. For example, the outer skin may be a moldable TPO or PVC which, during or prior to the molding process, acquires a suitable texture to serve its decorative function in the vehicle cockpit. The inner skin/decorative panel may also constitute a composite laminate preform, for example one or more GMT layers stitched, hot melt tacked, adhesively bonded, or the like, to a decorative trim material such as woven fabric, natural or artificial leather, carpet material, and the like. Multiple types of decorative trim material may be used in the same panel. In less preferred embodiments, the outer skin is not decorative or only partially decorative, and trim material is added following the molding process by traditional means, i.e., film adhesives.

In many cases, however, the outer structural skin and the decorative trim may be supplied as separate components which will be bonded into an integral

structure during the molding process. Thus, the structural outer skin may comprise one or more layers of GMT material, while the outer decorative trim layer may comprise woven fabric, carpeting, TPO, or the like. The structural inner skin and decorative trim may bond to each other by fusion or by use of an adhesive. Often, composite trim of flexible foam-backed PCV or TPO are used as trim materials. In this manner, a single layup and molding operation produces a "finished" door panel with a decorative visual surface.

The panel assembly will contain at least one foam stiffening component. The stiffening component may be a simple flat panel of foam material, or may be intricately molded to provide for aesthetically pleasing contours on the visual surface, or to accommodate window raising/lowering mechanisms, door locks, and the like. In suitable designs, the armrest may be molded integral with the remaining components. By the term "visual surface" is meant the outer surface of the panel assembly which faces the passenger compartment and will be visually observable by the vehicle occupants. The foam panel may be a single panel or may constitute multiple panels. The panels may be made of the same material or of different materials. Suitable materials, for example, include polyurethane foam, expanded polyolefin (EPO), particularly expanded polyethylene and expanded polypropylene (EPE and EPP, respectively, and their various copolymers), expanded polystyrene, heat-modified polyurethane, and the like. Other materials with the requisite stiffening capability and/or energy absorbing capabilities such as syntactic foams, may also be used. All these materials are termed foam stiffening compounds or panels, or "energy absorbing panel(s)", depending on their function. As explained herein, it is possible for a single foam insert to serve both functions.

The foam stiffening component is generally premolded. In the case of polyurethane foam, for example, the foam is generally prepared by injecting the reactive resin and isocyanate components into a closed mold and allowing the reactants to cure to form the polyurethane foam, employing water, lower alkanes and alkane ethers, or less preferredly halogenated hydrocarbons as cell-producing blowing agents. Complex shapes can be produced in this manner. The foams may

be rigid or semiflexible. In addition to these foam stiffening components, the panel assembly may also include sound and/or vibration absorbing panels.

Expandable thermoplastics such as EPO and EPS can be blow molded into foam stiffening components by introducing expandable particles into a steam chest and expanding with steam, a process which is now well known. Complex shapes can in general also be made using such processes. Molten thermoplastic containing a blowing agent under high pressure can be injected into a low pressure mold to produce panels as well. Panels may also be cut by saw, water jet, laser, or other means from previously prepared foam. However, the molding process is preferred, especially for its economical use of raw materials. Syntactic foam may be prepared from hollow polymer or glass beads, even natural "puffed" materials, e.g., puffed cereal grains, surrounded by a thermoplastic or thermoset resin. Energy absorbing foam panels may be made by the same processes.

During production of the panel assemblies, the structural inner skin, foam stiffening component, structural outer skin, and decorative trim, if different from the outer skin, are introduced into a mold and consolidated to form an integral structure, the inner structural skin and outer structural skin substantially enveloping the foam stiffening component so as to create a high strength and modulus panel of the stressed skin type. In a less preferred embodiment, a reactive expandable reaction mixture, i.e., one which will form a rigid or semi-flexible polyurethane foam may be introduced into a cavity formed between inner structural skin and outer structural skin while in the mold, forming the foam *in situ*.

In order for the panel assembly to perform its many functions, it is necessary that the foam stiffening component be encased sufficiently within the now-unitary inner and outer skins such that significant resistance to bending and other loads may be achieved. Thus, it is necessary for at least a portion of the inner and outer skins to meet beyond the periphery of the foam stiffening component panel, and to be bonded to each other. Preferably, this bonding takes place along the majority of the periphery of the panel assembly, i.e., greater than 50% of the lineal periphery of the stiffening foam, more preferably over a substantial portion, i.e.,

about 70% or more, and most preferably over a most substantial portion, i.e., about 85% or more of this periphery. It is preferred that the inner and outer skins be bonded to each other over their entire periphery.

It is also necessary that significant bonding take place between the inner and outer sides of the foam stiffening component and the inner and outer skins. In this manner, maximum strength and a stressed skin sandwich structure is obtained. Most preferably, substantially all the major surfaces of the foam, i.e., the more or less planar inner and outer surfaces should be bonded to the skins. However, it is also possible to bond only portions of the stiffening component, i.e., by use of a geometric array of adhesive points or lines. Most preferably, however, the entire surfaces are bonded.

The stiffening panels may be mechanically fixed to the skins, for example by molding or introducing a series of ridges or other texture to the panels into which the skin material encroaches during molding; by exhibiting an open, coarse cell structure into which skin material may penetrate during moldings; by fusing the panel to a compatible thermoplastic or thermosetting resin; or by adhesively bonding the panel to a thermoplastic or thermoset skin. The term "bonding" herein includes all these methods of fixing the panel to the skins. Preferably, as stated previously, virtually the entire surface of the panel will be adhered to the skins, preferably by fusing, by adhesive bonding, or by thorough and relatively uniform mechanical bonding. It is preferable that the use of adhesive films be minimized or avoided entirely.

In the case of EPO foam panels and either TPO or GMT skins, the bonding may be accomplished by fusion. In the case of stiffening foam polymers and skin polymers which are not compatible, i.e., do not fuse at reasonable temperatures to form a fusion-type bond, or which form no bond or only a weak bond, adhesive may be used. The adhesive may be a film adhesive, hot melt adhesive, liquid adhesive, or the like. Film adhesives, and hot melt adhesives which can be extruded or sprayed onto the foam panel and/or the panel-adjacent surface of the inner and/or outer skins are preferred.

Due to the strength and modulus which is exhibited by the panel assemblies of the subject invention, the steel door inner which serves as attachment points for the pull strap and arm rest may be dispensed with completely in suitable designs, as may also be the portion of the door inner which strengthens the "belt line". The composite assembly may be engineered with inner and outer skins dimensioned to absorb the horizontal and vertical loads imposed by components such as window mechanisms, drive motors, etc. For example, the geometry may be altered in known manner around attachment points to confer greater local strength, for example by engineering "dimples" or other strengthening geometric features into the panel. Alternatively, the attachment points may be reinforced, either by additional local layers of inner and/or outer skin material, by use of polymer bushings or other inserts, or by use of metal plates or inserts at these locations. While an entire steel member similar to those separately used in conventional construction can in theory be made part of the panel assembly, it is the purpose of the present invention to avoid its use, both to minimize weight as well as to avoid the separate production of a stamped metal part. Thus, it is preferred that metal support members of significant dimension be absent.

It has been surprisingly discovered that use of foam stiffening panels at appropriate locations within the panel assembly is effective to provide a structure sufficient for attachment of arm rests, pull straps, and other components such as window mechanisms while exhibiting far lesser weight and cost as compared to conventional construction. Moreover, it has also been surprisingly discovered that a further component, the energy absorbing foam panel, may also be included. This energy absorbing foam may often be made of the same material as the foam stiffening component, although different foams may be used as well. The energy absorbing foam panel may be a separate part or may be molded integrally with the foam stiffening component; i.e., one component, suitably dimensioned, may serve both purposes.

Inclusion of the energy absorbing foam into the panel assembly is preferred, as this leads to greater incorporation of separate components so as to effect even greater weight and cost savings.

The invention may be illustrated by the Figures, but should not be considered as limited thereby. Figure 1 illustrates a portion of a conventional vehicle door assembly. Note the vehicle door, showing the steel stamped exterior panel 1 and the door inner 2. As can be seen, the door inner is a substantial and rather complex stamping. At 3 and 4 are holes for mounting the pull strap/arm rest, while in the area of 5 are mounting flanges/holes for window mechanism 6, with accompanying bolts, nuts, pins, brackets, etc., all numbered 8, and motor 9. The door inner extends into the belt line 7 to support the panel along the window opening. Not shown are the energy absorbing foam panel, inner skin, and decorative trim. Figure 2 is a cross-section of a panel assembly of the present invention. At 10 is the GMT inner skin, which will be located in the door nearest the steel door panel. The outer skin 12 will be located on the side of the foam stiffening component panel 14 nearest the passenger compartment. Over the outer skin 12 is decorative trim 14. Decorative trim 14 is in this case TPO backed by flexible polypropylene foam. This construction represents a preferred embodiment.

Figure 3 represents an embodiment where the outer skin 12 is in part both a structural member and decorative trim. This outer skin, made of TPO, is embossed to have a leather like appearance over portion 12a. At portion 12b, the TPO has mounted superficial thereto, a section of carpet-type trim 15, secured to the TPO by film adhesive 13. The inner skin 10 is of GMT material. Note that the foam stiffening panel 14 is made thicker at 16 to serve as the energy absorbing foam component. The TPO 12 and GMT 10 are consolidated around the periphery of foam stiffening panel 18 at 17. Figure 4 represents a layup of GMT inner skin 10, foam stiffening component panel 14, GMT outer skin 12, and TPO trim layer 14 which is consolidated between mold halves 18 and 19.

The molding process generally requires only low tonnage equipment, which is highly advantageous. Molding procedures are conventional for the plastics molding industry, and may utilize heated or unheated molds, depending upon the particular substrates. For example, if fiber reinforced sheet molding compound is used, a heated mold is generally required. However, with many substrates, e.g., natural leather trim and woven polypropylene fabrics, excessive heat may damage

such trim. Non-heated molds or molds which are heated only to low temperatures are preferred for such trim materials. Use of GMT and similar products, i.e., flax-filled polypropylene, is advantageous, since the substrate may be surface heated, e.g., by infrared radiation, or heated by a combination of through-heating and surface heating, laid up into the sandwich structure precursor, and molded under modest pressure in an unheated or only modestly heated mold, or even a cooled mold where appropriate. The GMT can be fully or partially consolidated. A gapped mold is preferably used, as disclosed in U.S. Patent 5,900,300, to avoid crushing the energy absorbing panel. Only partial consolidation of the GMT or other substrate is generally required.

Figure 5 illustrates a molding method employing a gapped mold where easy layup is achieved by extending TPO layers, GMT layers, etc., beyond the mold cavity, and cutting off the excess as the mold is closed. Figure 6 illustrates a completed door panel without hardware (armrest, etc.). Figure 7 illustrates a "serpentine" stiffening panel, adapted in shape to provide suitable strength for arm rest attachment, door pulls, etc., while minimizing. In Figure 7, the foam stiffening panel at 30 provides support for the armrest 31 whose position is indicated by dotted lines, and where loads are substantially vertical, while at 32, pull strap loads, substantially horizontal, are provided for. The location of the pull strap 33 is shown by dotted lines, while holes 35 are for mounting pull strap and arm rest. At 34, the foam stiffening member supplies bending stiffness for the beltline region, whereas at 36, an increase in depth allows the stiffening component to also serve as the energy absorbing panel. Stiffening of the door bottom is achieved by foam stiffening panel portion 38.

Figure 8 illustrates that the sandwich panel of the present invention possesses serious load bearing capacity at minimal deflection. In the test, a panel, prepared in accordance with the invention, is supported on pillars at each end, and a through hole bored in the center to accommodate a bolt, for example one of 1/4 inch diameter. A ca. one inch diameter washer distributes the load of the bolt head, and pressure is applied. Figure 8 shows that a loading in excess of 300 lb-ft. can be obtained. Bending of the panel, even at this load, is only about one inch (2.54 cm).

7. The panel assembly of claim 1, wherein the panel assembly is configured to mount a window raising and lowering mechanism.

8. The panel assembly of claim 1 wherein said stiffening component does not occupy substantially the entire interior of the panel, but is of serpentine construction.

9. In a process for the assembly of a vehicle door having an attached armrest and pull strap or combination thereof, the improvement comprising supplying an integral panel assembly comprising:

a) an inner structural skin of moldable polymer;

b) a foam stiffening component;

c) an outer structural skin of moldable polymer;

d) optionally a decorative trim layer,

wherein components a) through d) are consolidated in a mold to an integral panel assembly wherein the inner structural skin is bonded along its periphery to the outer structural skin, and wherein both of said structural skins are bonded to foam stiffening component.

10. The process of claim 9 wherein said integral panel assembly further comprises an energy absorbing foam panel.

11. The process of claim 10, wherein said energy absorbing foam panel and said foam stiffening component panel are a unitary component providing both stiffening and energy absorbtion.

12. The process of claim 9, wherein said inner skin and said other skin are prepared from materials selected from the group consisting of TPO, glass fiber-filled polyolefin, and natural fiber-filled polyolefin.

13. The process of claim 12 wherein said decorative trim layer is present and comprises TPO backed by a polyolefin flexible foam.

14. A method of producing a vehicle door panel assembly, comprising:

a) selecting an at least two part mold having a first part cavity with a visual surface contour which is the negative of a desired visual surface contour of said panel assembly, and a second part cavity with an inner contour which is the negative of an inner skin of said panel assembly;

b) laying up into said mold between parts of said at least two part mold, a layup comprising, in order from the inner contour of the second mold part cavity,

b)i) an unconsolidated inner structural skin;

b)ii) a foam stiffening panel;

b)iii) an unconsolidated outer structural skin; and

b)iv) optionally a decorative trim layer;

c) closing said mold to consolidate said skins b)i) and b)iii) together to form an integral structure bonded together along a periphery surrounding said foam stiffening panel, and bonding said foam stiffening panel to both of said skins b)i) and b)iii); and

d) removing from said mold a vehicle door integral panel assembly having a visual surface with a contour corresponding to said visual surface contour of said first mold part.

15. The process of claim 14 wherein at least one of said skins b)i) and b)iii) comprise one or more layers of fiber reinforced thermoplastic.

16. The process of claim 14 wherein at least one of said skins b)i) and b)iii) comprise a GMT material.

17. The process of claim 14 wherein said layup further comprises an energy absorbing panel which is a molded panel of expanded polyolefin or molded polyurethane foam.

18. The process of claim 14 wherein disposed between said energy absorbing panel b)ii) and at least one of said skins b)i) and b)iii) is an adhesive.

19. The process of claim 15 wherein said inner structural skin b)i) is first bonded to said energy absorbing panel before being layed up into said mold.

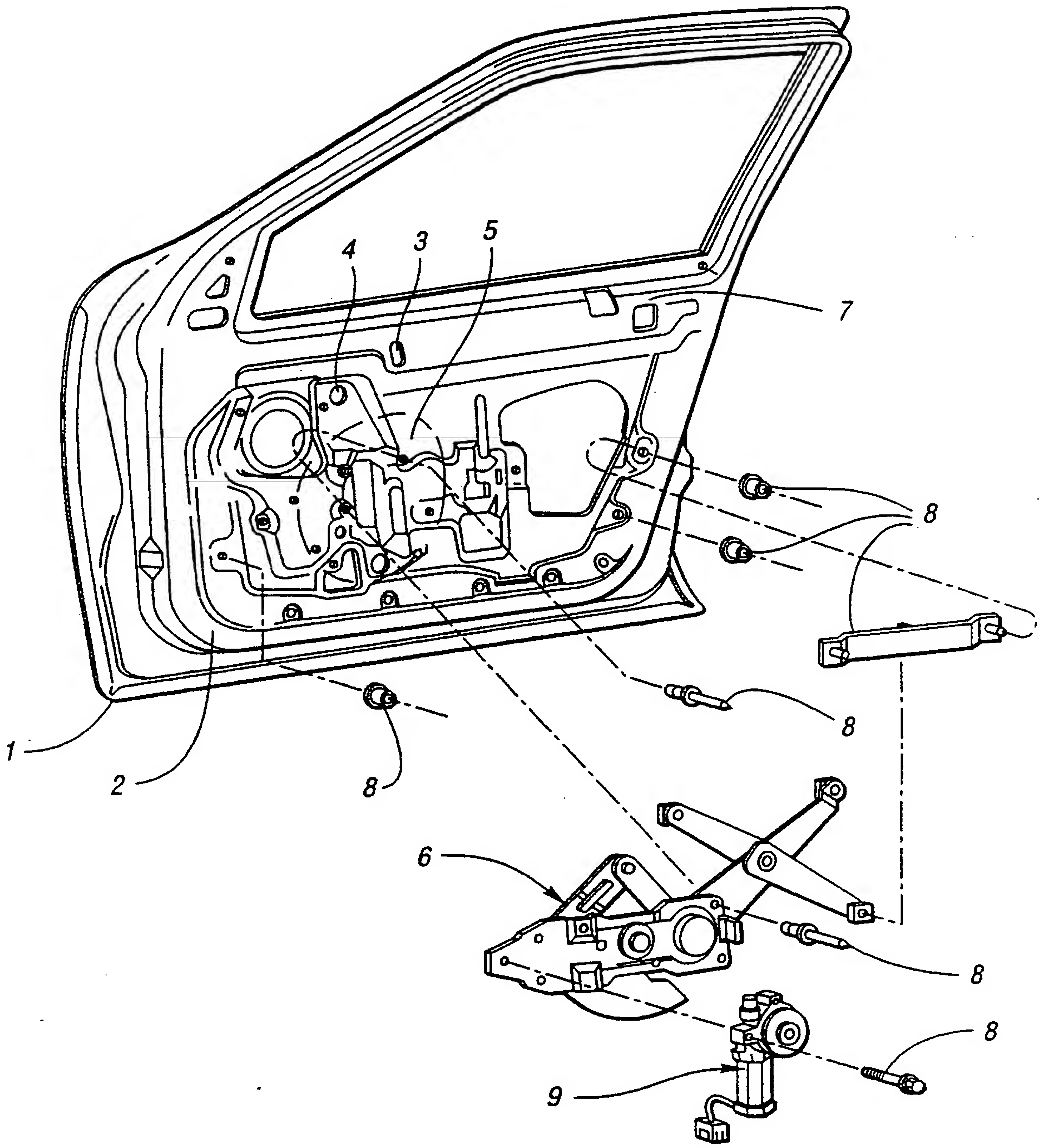


Fig. 1
(PRIOR ART)

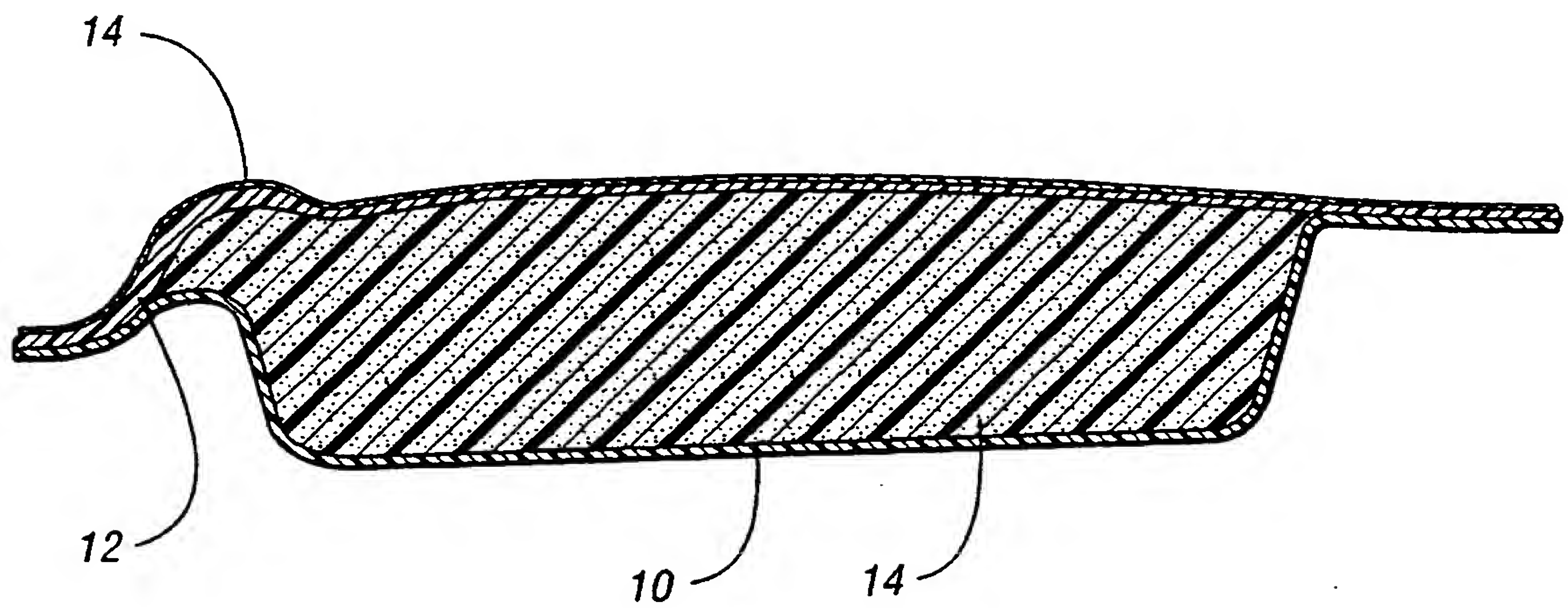


Fig. 2

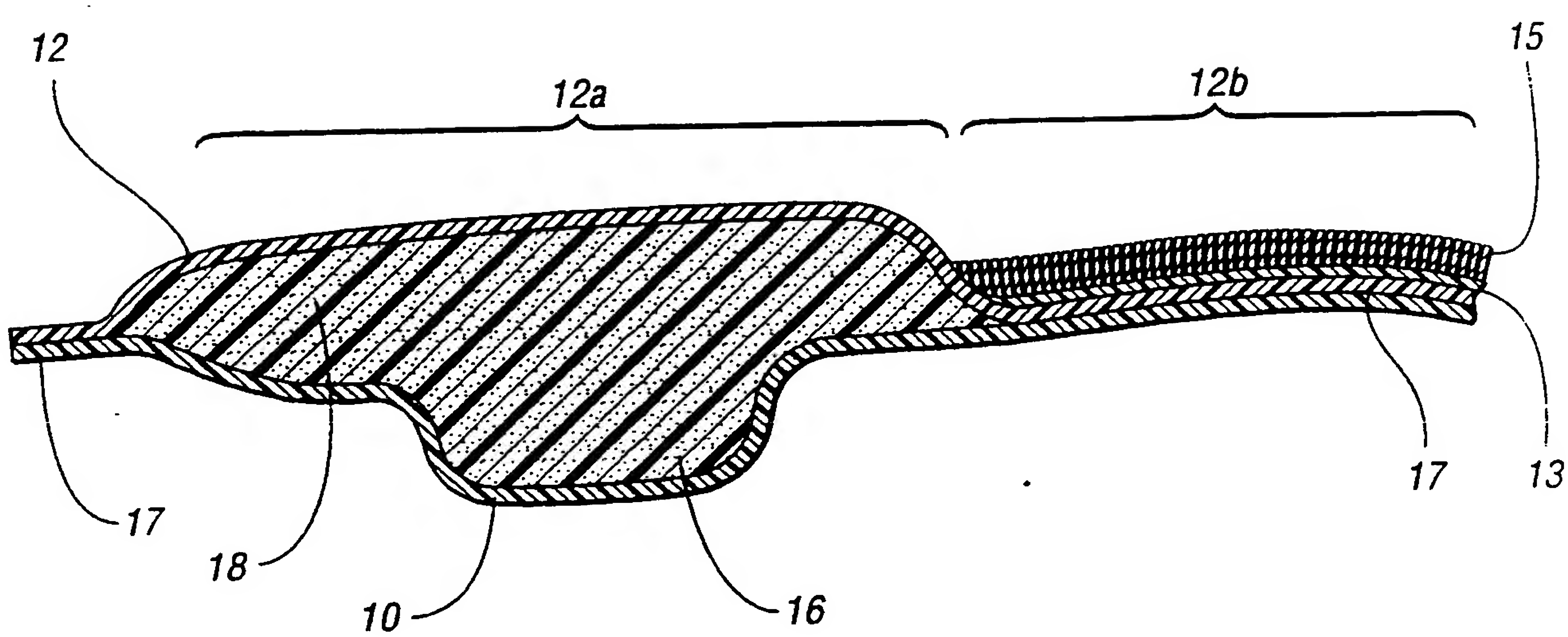


Fig. 3

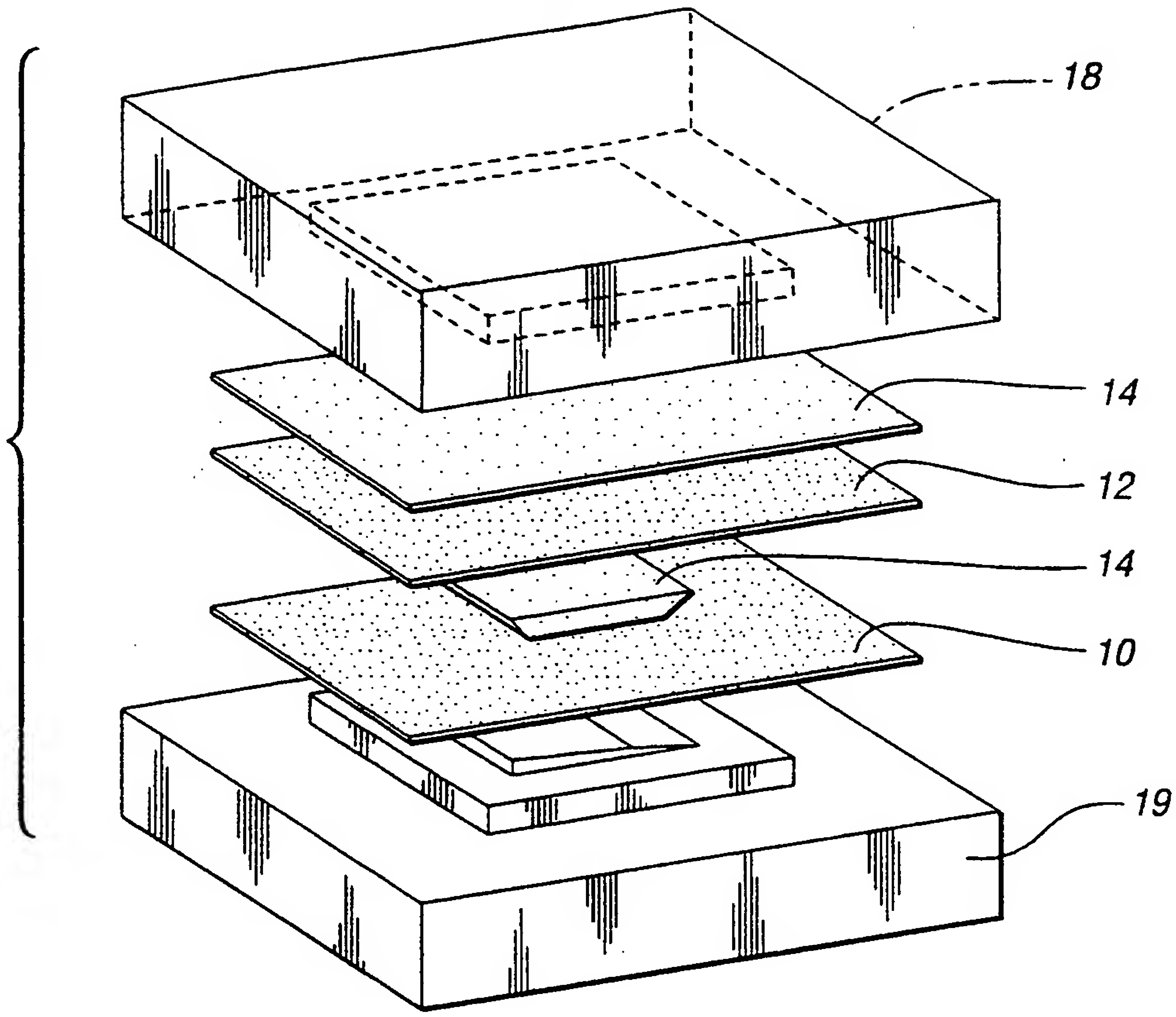


Fig. 4

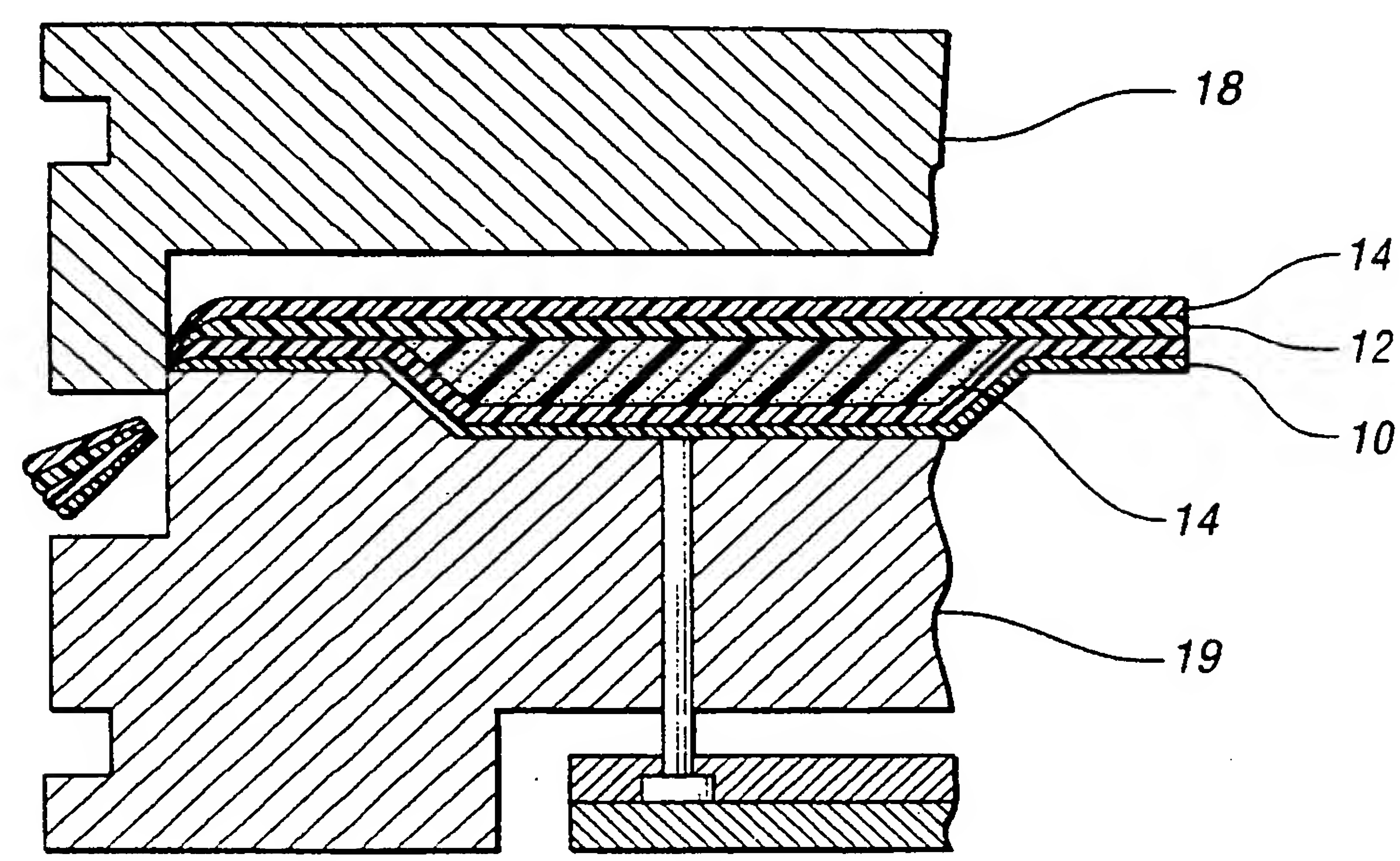


Fig. 5

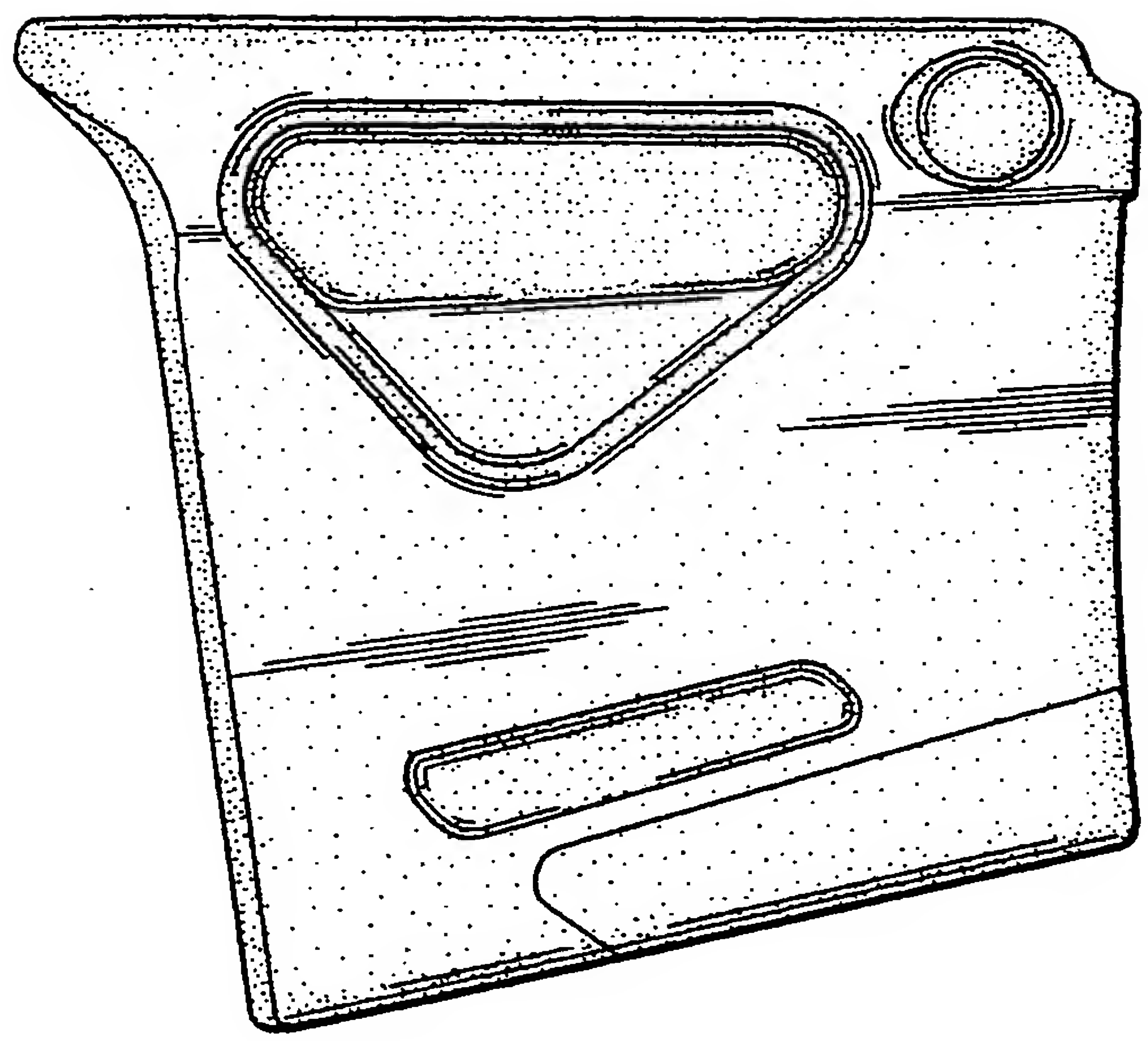


Fig. 6

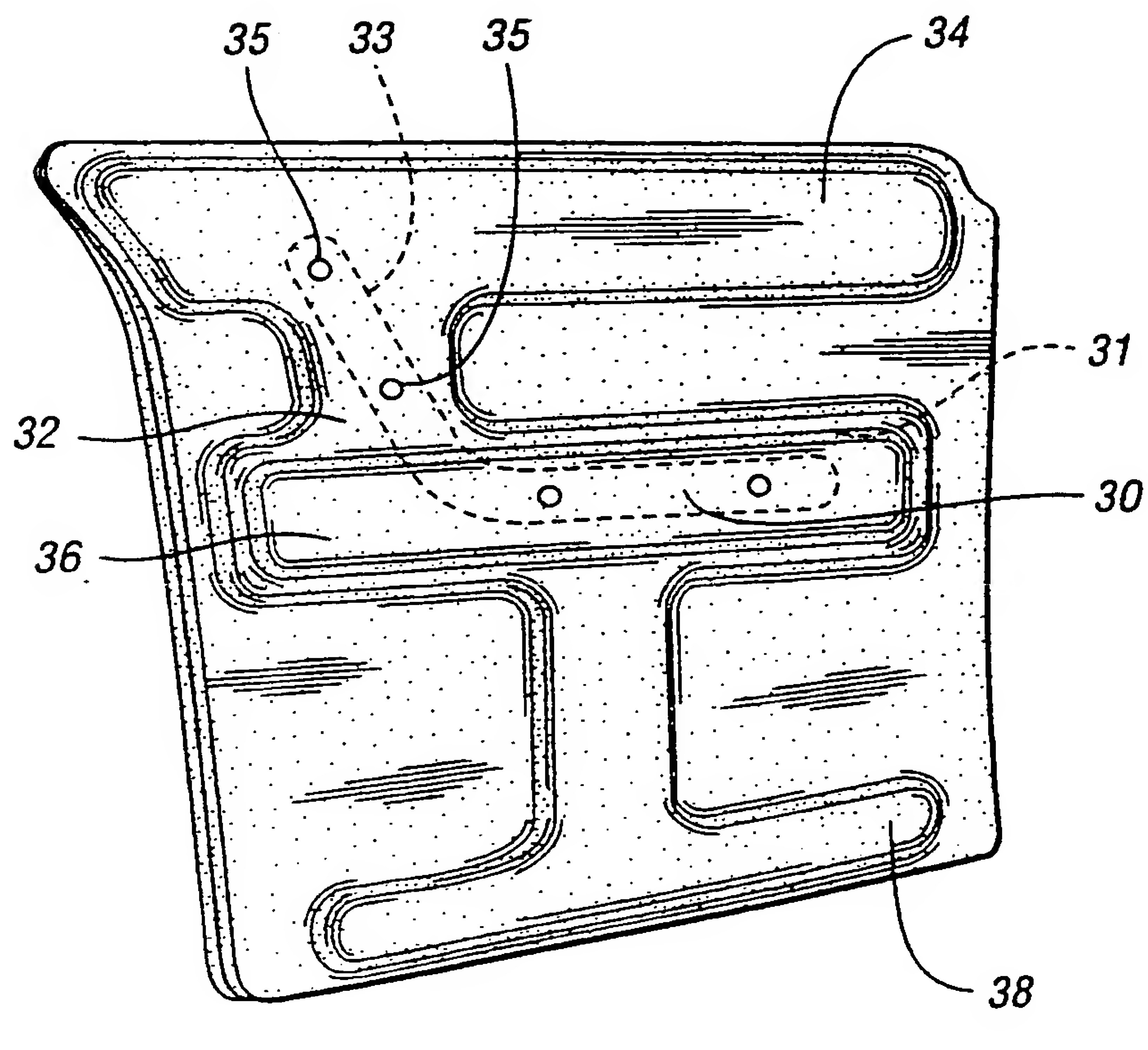


Fig. 7

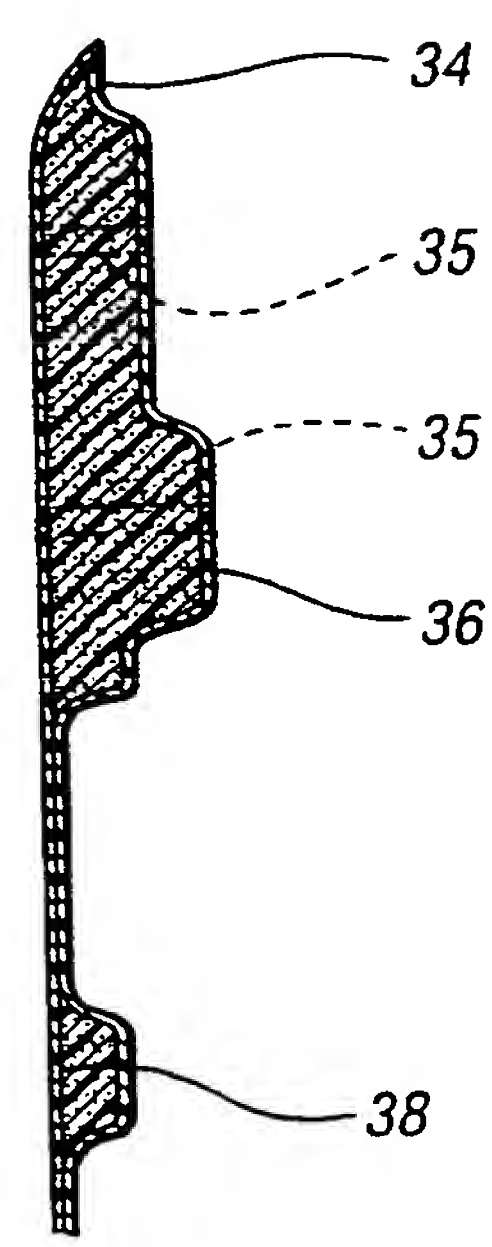
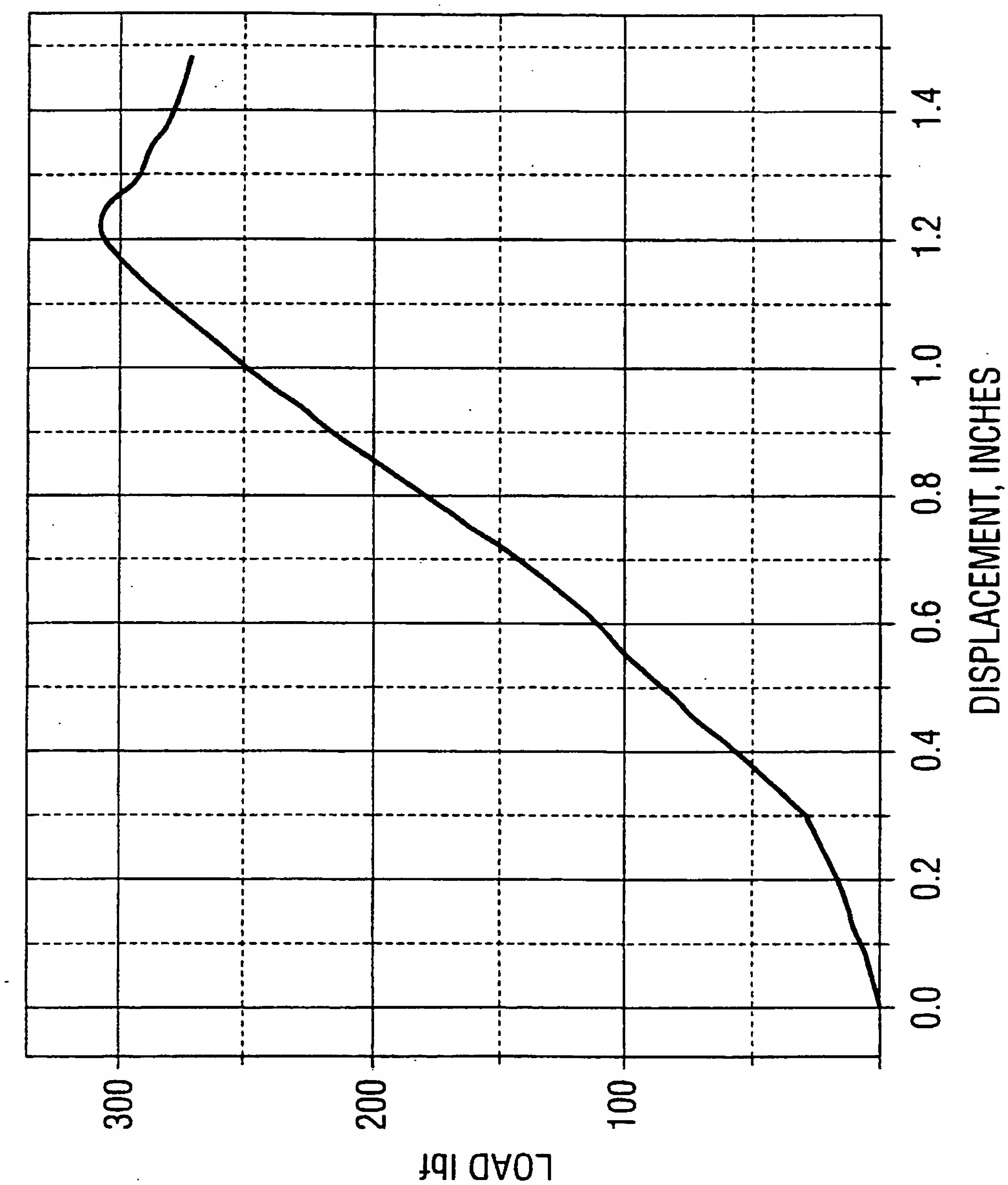


Fig. 7a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DISPLACEMENT, INCHES

Fig. 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/26745

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B60R13/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B60R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X A	US 5 837 172 A (PRITCHARD JAMES R ET AL) 17 November 1998 (1998-11-17) the whole document	1,9,14 2-5,10, 11,16-19

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 January 2001	19/01/2001
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Kusardy, R

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International Application No
PCT/US 00/26745

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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..formation on patent family members

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